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Embracing Industry 4.0: Navigating the Evolution of Entrepreneurship in Romania

By Iolanda-Petronela Grosu[1], Leonard-Alin Rizoiu[2], Andrei-Edward Dinicu[3], Xiaoliang Zhang[4]

ABSTRACT:
Entrepreneurship constitutes one of the oldest and most profitable occupations. It has evolved alongside the Industrial Revolutions (IR), directly influencing each other. One of the fundamental pillars of technological development is represented by inventive and innovative entrepreneurs who had the courage to investigate and implement what initially seemed to be mere dreams. The first three IRs brought major and decisive changes on a global level. The fourth revolution, called Revolution 4.0 - R 4.0 (or Industry 4.0 - I 4.0), which we consider an evolution, has brought to the forefront new fields of interest and heterogeneous areas of concern: artificial intelligence, robotics, automation, the Internet of Things, 3D printing, etc.
In our research, we aimed, on the one hand, to analyze the perspective of Romanian entrepreneurs regarding IR 4.0, whether they implement measures specific to new technologies, and what the impact of these measures is. On the other hand, following the analysis of the collected data, we sought to identify possibilities for stimulating local entrepreneurship under the new R 4.0 conditions. Noting that, still, in Romania, there is insufficient investment in the necessary technological infrastructure, we began our research with a theoretical analysis of the data and the state of the specialized literature. The specific infrastructure that Romania lacks includes reliable broadband internet connectivity, advanced digital technologies such as IoT devices, and accessible automation tools. These gaps significantly hinder the ability of entrepreneurs to leverage Industry 4.0 advancements, thereby limiting their capacity to innovate and compete globally. Addressing these issues will require targeted government investments in digital infrastructure, incentives for technology adoption in key sectors, and partnerships between the private and public sectors to accelerate the deployment of Industry 4.0 technologies. In the next stage, we analyzed the data collected through a semi-structured questionnaire disseminated via crowdsourcing, to which 1026 subjects responded. Before conducting the econometric analysis of the data, three research hypotheses were formulated, which were ultimately validated.
The working methodology included quantitative data analysis, descriptive statistics methods, categorical principal component analysis (CATPCA), and correspondence analysis. Data processing was performed using the IBM SPSS 20 application. A limitation of our research is that we did not select the questionnaire participants based on their competencies, allowing individuals with still limited knowledge to intuitively express opinions on a field they do not know or only think they know. The lack of competency-based selection for survey participants means that respondents may not have had the requisite knowledge to provide informed opinions, potentially skewing the results. This limitation impacts the reliability of the data and could mean that the findings are not fully reflective of expert perspectives in Industry 4.0. Future studies should consider a more rigorous selection criterion, ensuring participants possess relevant competencies. This approach would help in obtaining more accurate insights, leading to more actionable conclusions. As a future action direction, we aim to analyze the issue of local entrepreneurship by involving respondents from different professional categories who possess the necessary competencies, so that their opinions can form the basis of a more detailed analysis. This would facilitate establishing viable action directions as a basis for the sustainable and enduring development of entrepreneurship in Romania in the context of the Fourth Industrial Revolution.

[1]Bucharest University of Economic Studies, Romania
[2]Bucharest University of Economic Studies, Romania
[3]Bucharest University of Economic Studies, Romania
[4]Bucharest University of Economic Studies, Romania

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1. Introduction

The development of entrepreneurship has been primarily achieved with the help of industrial revolutions (IR). In the 18th century, the first industrial revolution took place, bringing significant changes and having a profound impact on production. The first IR was marked by the emergence of inventions and innovations, with some of the most important aspects including the use of new technologies (e.g., the steam engine), the increase in production through the optimization of processes, the creation and development of new industrial branches (e.g., textiles, steel, mining), and the improvement of mobility through the development of transportation (Ciasullo, Calabrese & La Sala, 2023).

The second industrial revolution occurred between 1870 and 1914, as a direct consequence of the development of the world's economic powers. Among the most important aspects characterizing the second IR were the emergence of new technologies (electricity, the internal combustion engine, the television, etc.); the increase in the degree of industrialization; the development of transportation (diversification of transportation modes such as the automobile, as well as the development of transportation networks); and the globalization of trade.

The third IR (or the digital revolution) began in the early 1970s and continues to this day, overlapping with the fourth industrial revolution. Its peak was marked by the advent of a new energy source, nuclear energy. Other major elements of importance for this revolution were the development of digital technology (the emergence of personal computers, mobile phones, cloud data storage, etc.); the automation and robotization of industries and various branches, facilitating increased productivity and efficiency; electronic commerce and globalization; and digital innovations that led to efficiency gains and productivity growth, as well as changes in social and cultural relationships (Mohajan, 2021).

IR 4.0 or I 4.0 has brought emerging technologies to the forefront: advanced automation, artificial intelligence, IoT, 3D printing, and other digital innovations (Pisal, Razdan & Kalaskar, 2019). The most important characteristics of this revolution are: automation and robotization, interconnectivity, artificial intelligence, virtual and augmented reality, big data, data analysis, renewable energies, and 3D printing (Aoun, Ilinca, Ghandour & Ibrahim, 2021). In this article, we will present ways in which local entrepreneurship can be stimulated in the context of the development of this industry.

2. Literature Review

Since ancient times, entrepreneurship has been one of the most important drivers of economic growth. There have been various definitions of entrepreneurship over time. Thus, entrepreneurship has been seen as a process through which we start and manage a business (Amoros et al., 2021), aiming to identify available market opportunities and

transform them into viable products or services (Kim & Mauborgne, 2015). When discussing entrepreneurs, we refer to individuals who take risks and possess a developed innovative spirit to start their own businesses (Freedman, 2023; Michail, 2023). Entrepreneurship is an activity that generates professional satisfaction but is also challenging, involving the management of complex issues such as obtaining resources, hiring and motivating employees, marketing, risk management, etc. (Yu et al., 2023). Entrepreneurs play an extremely important role in the economy, helping to create jobs, stimulating innovation, and improving living standards (Litan & Schramm, 2023).

The industrial revolutions have had a major impact on the development of entrepreneurship, just as the innovations of various entrepreneurs have led to the emergence of new technologies. The concept of "IR 4.0" ("I 4.0") officially appeared for the first time in 2011 in Germany at the Hannover Messe, in a report ("Smart Manufacturing for the Future") prepared by researchers in the service of the government (MacDougall, 2014). One of the fundamental characteristics of this industry is interconnectivity, the ability of systems and devices to communicate with each other via the internet. In this way, the integration and coordination of processes worldwide can be achieved more efficiently and productively (Munirathinam, 2020), even during the SARS-CoV-2 pandemic crisis (Chatterjee et al., 2023).

Additionally, artificial intelligence plays an extremely important role, along with advanced automation. AI systems enable various devices to learn and adapt to the environment, leading to a significant increase in productivity (Akash, 2023). The Internet of Things (IoT) is a key technology that has enabled the monitoring of device activity and the control of processes in real-time (Li & Lau, 2019). As a result of these improvements, better management and enhancement of efficiency and workplace safety have been achieved (Marinagi et al., 2023). Another important aspect of I 4.0 is 3D printing, which allows the production of objects using successive layers of material, offering increased flexibility for prototyping and manufacturing parts and products, reducing both costs and production time (Agnesina et al., 2023).

3. Research Methodology

An exploratory research methodology of a quantitative type was used. The working method employed was the opinion survey, which served as the support for data collection through a structured questionnaire. The sampling methods were mixed, with 1026 respondents participating in our study. After the quantitative data analysis, descriptive statistics methods, categorical principal component analysis (CATPCA), and correspondence analysis were used. Data processing was performed using the IBM SPSS 20 application.

3.1 Research Hypotheses

In our research, we started with the following three basic research hypotheses:

I1: With the help of Industry 4.0, Romanian entrepreneurs have been able to more easily identify business development opportunities and have adopted the best strategies, regardless of their field of activity.

I2: The development of Industry 4.0 is based on the growing number of entrepreneurs who are turning to new technologies and universities, which act as true development vectors.

I3: The IT&C field is the main direction for the development of Industry 4.0, as well as for the modern, technology-based entrepreneur.

Before describing the variable testing process, we will present some demographic data and information related to the survey respondents.

From a gender perspective, the majority (64.1%) of responses were from men, and in terms of education level, 38.7% have a master's degree, 33.1% have a university degree, followed by those with high school, postgraduate, and primary education.

At the time of the research, 90.4% of the respondents owned a business, making the responses relevant to the analysis undertaken. They operate in various fields, with the top three being: tech and innovation (30.1%), financial services (21.2%), and green energy (16.5%). Responses regarding the current challenges faced by entrepreneurs in Romania can be observed in tab. no.1.

Table no. 1: What are the most common problems faced by entrepreneurs

Complex regulations and excessive bureaucracy	144	14%
Limited and even restrictive access to financing	236	23%
Inadequate infrastructure	170	16.6%
Corruption	181	17.6%
Human Resources	137	13.4%
Economic uncertainty/unpredictability	88	8.6%
Prefer not to answer	70	6.8%
Total responses	**1 026**	

***Source*:** *answers processed by the authors*

We observe that "company financing" and "corruption at the national level" are the most frequently indicated responses in the questionnaire. From the perspective of how open the Romanian market is to new and innovative businesses, 33.6% of respondents consider it to be "very open," while, at the opposite end, 13.9% of respondents consider it to be "not open at all." The other responses are distributed between these two options, but the total exceeds half of the responses regarding "market openness." A relevant question for the research undertaken is about the impact that respondents believe modern technologies have on entrepreneurship in our country (tab. no.2).

Table no. 2: The impact of modern technologies on entrepreneurship

It will improve business efficiency	201	19.6%
It will help access new markets and distribution channels through the internet	51	5%

It will increase the accessibility of information	237	23.1%
It will create collaboration opportunities through online platforms	54	5.3%
It will increase the competitiveness of products and services through technology	159	15.5%
It will increase business flexibility	257	25%
Prefer not to answer	67	6.5%
Others (please specify)	0	0%
Total responses	**1 026**	

Source*: *answers processed by the authors

Respondents also consider that I 4.0 is a true vector of sustainable development, both socially and economically (*average score = 8.35*), that it represents a fundamental pillar for building a sustainable future based on solid economic principles (*average score = 7.35*), and that it is a development engine only for certain sectors, especially those in the IT&C area (*average score = 7.15*). Industry 4.0 technologies are not limited to the IT&C sector; they have substantial impacts on other sectors such as agriculture and manufacturing. For instance, in agriculture, the use of IoT and automation can enhance precision farming, optimize resource use, and increase productivity. In manufacturing, the implementation of robotics and automation can streamline production processes, reduce costs, and enhance quality control. By integrating Industry 4.0 technologies across these diverse sectors, Romanian entrepreneurs can create new opportunities for innovation and expand their competitive advantage beyond the digital industries. In close connection with the presented information, in tab. no.3, we can analyze which sectors, in the respondents' opinion, will develop the fastest as a result of the implementation of I 4.0 in Romania, as follows:

Table no. 3: Sectors that will develop as a result of the implementation of 4.0 technologies

The technology and IT&C sector	141	13.7%
The automotive industry	39	3.8%
Energy production and distribution	198	19.3%
Logistics and transportation sectors	111	10.8%
Food processing and agriculture	302	29.4%
Durable consumer goods production	189	18.4%
Prefer not to answer	46	4.5%
Others (please specify)	0	0%

Total responses	**1 026**	

***Source*:** *answers processed by the authors*

We observe a fairly varied distribution of responses, with the automotive sector being the least targeted, according to the respondents. Additionally, the opinion regarding the role of the educational sector in the development of I 4.0 in Romania is also important (tab. no.4):

Table no. 4: The role of universities and the education system in the development of 4.0 technologies

Trains specialists	263	25.6%
Forms partnerships with the industrial sector	186	18.1%
Researches advanced technologies	17	1.7%
Offers study programs adapted to industry requirements	55	5.4%
Provides internships	266	25.9%
Organizes conferences and workshops	205	20%
Prefer not to answer	34	3.3%
Total responses	**1 026**	

***Source*:** *answers processed by the authors*

As we can see, the main three directions in which universities and the education system support the development of technology are: training specialists, providing internships, and organizing conferences and workshops. To deepen these collaborations, specific educational reforms are necessary. Universities should introduce specialized programs focused on Industry 4.0 technologies, such as courses on IoT, AI, and robotics, tailored to the current needs of the industrial sector. Partnerships can also be expanded to include more joint research projects, funding for innovation centers, and enhanced internship programs that provide real-world exposure to emerging technologies. Such initiatives would ensure that students are well-prepared for the technological demands of modern entrepreneurship, enhancing their ability to innovate and succeed in the Industry 4.0 landscape.

From the perspective of collaboration between public and private systems, 45.3% of respondents consider this link crucial, while 23.2% consider it important. Only 5% of respondents do not consider the collaboration between the private and public sectors important. Incorporating technology into a company's business strategy is extremely important, and in tab. no.5, we can observe the improvements that respondents believe it can bring:

Table no. 5: The role of technology in the company's development strategy

It can improve business process efficiency and automation	256	25%
It can provide a competitive advantage through innovation and unique solutions	308	30%
It can help in gaining and retaining customers	235	22.9%
It can reduce costs through automation and efficiency	102	9.9%
It can open new business opportunities and markets	20	1.9%
It can help in obtaining financing	46	4.5%
Prefer not to answer	59	5.8%
Total responses	**1 026**	

***Source*:** *answers processed by the authors*

3.2 Hypotheses Testing

Due to the limitation of the scope of this work, we will mention only a few econometric aspects, as the entire analysis is much more extensive.

I1 - With the help of Industry 4.0, Romanian entrepreneurs have been able to more easily identify business development opportunities and have adopted the best strategies, regardless of the field of activity.

To test the first working hypothesis, the correspondence analysis technique was used for two questions ("adaptation of 4.0 technologies by respondents" and "what technology can offer in a company's development strategy"). The causal links between the variables are highlighted using the independence test of response categories, $\chi 2$. In the null hypothesis, the studied variables are independent, with no connection between them. In the alternative hypothesis, there is a significant link between the analyzed variables when the value of the index v is higher than the critical table value, calculated using the data from the contingency table (tab. no.6):

Table no. 6: Correspondence Table

(22) What technology can offer in a company's business strategy?	(20) Have you adopted Industry 4.0 principles?			
	Yes	No	I don't know, the business operates on inertia.	Active Margin
Can improve efficiency and automation of business processes	23	12	11	46
Can provide a competitive advantage through innovation and unique solutions	132	126	50	308

Can reduce costs through automation and efficiency	43	36	23	102
Prefer not to answer	23	16	20	59
Active Margin	429	377	220	1 026

***Source*:** *answers processed by the authors in IBM SPSS 20*

The independence test indicated causal links between the two categories of variables studied (tab. no.7). In this context, we found that, for 12 degrees of freedom, the critical value calculated for χ^2 is 17.648 and, given that the tabulated critical value (18.549) is greater than the calculated one, we rejected the null hypothesis and concluded that the studied variables are dependent.

Table no. 7: Summary

Dimension	Singular Value	Inertia	Chi Square	Sig.	Proportion of Inertia		Confidence Singular Value	
					Accounted for	Cumulative	Standard Deviation	Correlation
	.111	012			.721	721	032	2
	.069	005			.279	.000	031	- .018
otal		017	17.648	127[a]	1.000	.000		

a. 12 degrees of freedom

***Source*:** *answers processed by the authors in IBM SPSS 20*

The graphical representation of the data from tab.no.2 confirms the links between the variables and, accordingly, the fact that Industry 4.0 helps entrepreneurs identify new ways to develop their businesses strategy (fig.no.1):

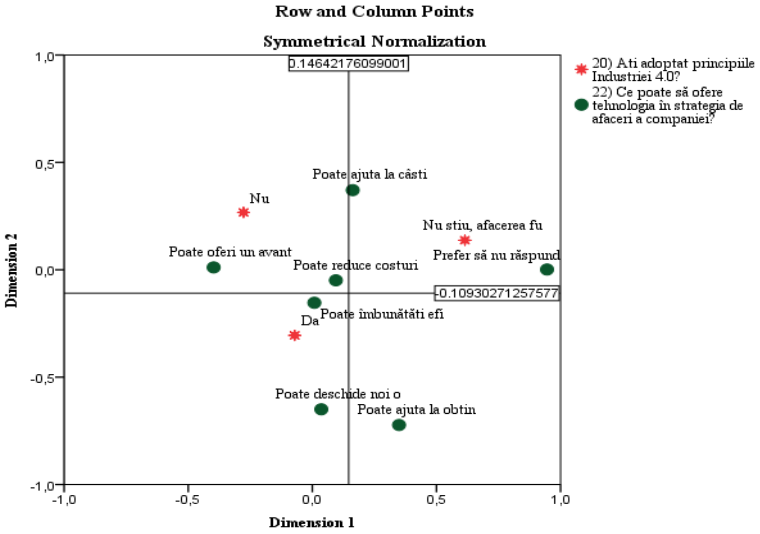

Figure no.1: Two-dimensional representation of the studied values
***Source*:** *answers processed by the authors in IBM SPSS 20*

Therefore, we confirm the first research hypothesis, according to which *"With the help of Industry 4.0, Romanian entrepreneurs have been able to more easily identify business development opportunities and have adopted the best strategies, regardless of the field of activity."*

I2 – The development of Industry 4.0 is based on the increasing number of entrepreneurs who turn to new technologies, as well as universities, which act as true development vectors

For the second research hypothesis, we used the optimal scaling technique, CAPTCA, aiming to interpret the responses to five questions: (1) the role of the educational system and universities in the development of Industry 4.0; (2) the willingness of companies to invest in this industry; (3) the results obtained by companies that have invested; (4) the role of technology in risk management and decision-making; (5) the advantages of implementing technologies in organizational management. With the help of the analysis technique, we extracted a number of latent factors common to a set of variables to identify how they explain the studied latent factor. The initial solution was identified after 20 iterations (tab. no.8), at which point the convergence criterion was met, with the increase in variation becoming insignificant.

Table no.8: Iteration History

Iteration Number	Variance Accounted For		Loss		
	Total	Increase	Total	Centroid Coordinates	Restriction of Centroid to Vector Coordinates
0[a]	4.860704	.000308	13.139296	9.502204	3.637092
1	5.065639	.204934	12.934361	9.502204	3.432157
2	5.213707	.148069	12.786293	9.692286	3.094006
3	5.503968	.290261	12.496032	10.235051	2.260980
4	5.743432	.239463	12.256568	10.824638	1.431930
5	5.802397	.058965	12.197603	11.026190	1.171413
6	5.818300	.015903	12.181700	11.091337	1.090363
7	5.824905	.006605	12.175095	11.124770	1.050324
8	5.828366	.003461	12.171634	11.149042	1.022592
9	5.830993	.002626	12.169007	11.170521	.998486
10	5.833855	.002862	12.166145	11.192085	.974060
11	5.837317	.003462	12.162683	11.215282	.947400
12	5.841560	.004243	12.158440	11.240519	.917920
13	5.846624	.005064	12.153376	11.267314	.886062
14	5.850768	.004144	12.149232	11.294337	.854895
15	5.851784	.001016	12.148216	11.311114	.837103
16	5.852032	.000248	12.147968	11.315266	.832702
17	5.852120	.000088	12.147880	11.316944	.830935
18	5.852158	.000037	12.147842	11.317773	.830069
19	5.852175	.000018	12.147825	11.318283	.829542

2	5.852	.000	12.147	11.318	.8291
0[b]	184	009	816	652	64

a. Iteration 0 displays the statistics of the solution with all variables, except variables with optimal scaling level Multiple Nominal, treated as numerical

b. The iteration process stopped because the convergence test value was reached

***Source*:** *answers processed by the authors in IBM SPSS 20*

As we can observe in fig.no.2, the results have highlighted the following: the educational sector and universities are appreciated by the respondents; there are advantages of technology in the decision-making process; companies are willing to invest in Technology 4.0 and there are positive results recorded by entities that have implemented Industry 4.0 principles.

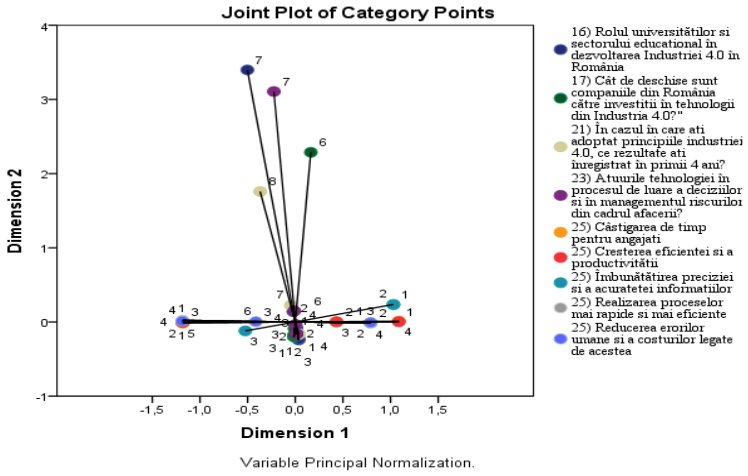

Figure no.2: The intersection of the vectors formed by the variables

***Source*:** *answers processed by the authors in IBM SPSS 20*

The graphical representation of the "point cloud" illustrates how the variables are associated and the stable connections between them.

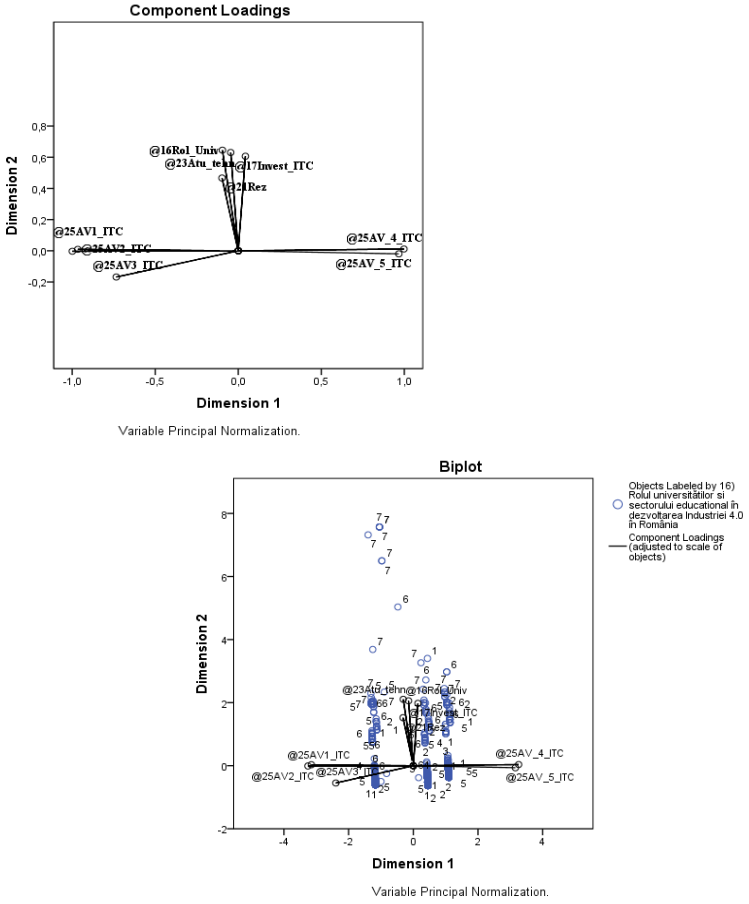

Figure no.3: The graphical representation of the principal components
***Source*:** *answers processed by the authors in IBM SPSS 20*

The degree of association between variables is determined by representing the connection between universities, technology, investments, results of technology implementation, and advantages of technology implementation. The association of 4 out of the 5 analyzed variables allowed us to validate the second working hypothesis - *the development of Industry 4.0 is based on the increasing number of entrepreneurs who turn to new technologies, as well as universities, which act as true development vectors.*

I3 – The IT&C field is the main direction for the development of Industry 4.0 and also for the modern, technology-based entrepreneur.

For the third research hypothesis, we also used the optimal scaling technique, and the analysis was conducted using the responses to the following three questions: the strengths in favor of developing relationships between entrepreneurs, the role of education

in the development of Industry 4.0, and the IT&C field representing a main component of the business. The solution was identified after 14 iterations, after which the convergence criterion was met and the increase in variance became insignificant.

Table no.9: Iteration History

Iteration Number	Variance Accounted For		Loss		
	Total	Increase	Total	Centroid Coordinates	Restriction of Centroid to Vector Coordinates
0[a]	4.575320	.000075	13.424680	9.796483	3.628197
1	5.907136	1.331815	12.092864	9.796483	2.296382
2	6.027373	.120238	11.972627	9.525188	2.447439
3	6.036461	.009088	11.963539	9.456550	2.506989
4	6.038089	.001628	11.961911	9.428518	2.533393
5	6.038680	.000591	11.961320	9.415782	2.545538
6	6.038973	.000293	11.961027	9.409345	2.551681
7	6.039139	.000165	11.960861	9.405792	2.555069
8	6.039238	.000099	11.960762	9.403681	2.557081
9	6.039299	.000062	11.960701	9.402414	2.558287
10	6.039339	.000040	11.960661	9.401588	2.559074
11	6.039364	.000026	11.960636	9.401012	2.559624
12	6.039381	.000017	11.960619	9.400591	2.560028
13	6.039392	.000011	11.960608	9.400275	2.560333
14[b]	6.039399	.000007	11.960601	9.400032	2.560570

a. Iteration 0 displays the statistics of the solution with all variables, except variables with optimal scaling level Multiple Nominal. treated as numerical

b. The iteration process stopped because the convergence test value was reached

***Source*:** *answers processed by the authors in* IBM SPSS 20

Using the graphical representation of the vectors corresponding to the three variables, highlight the length of the vector corresponding to the response category "prefer not to answer" in relation to the question about the strengths that represent reasons why entrepreneurs develop business relationships with other entrepreneurs.

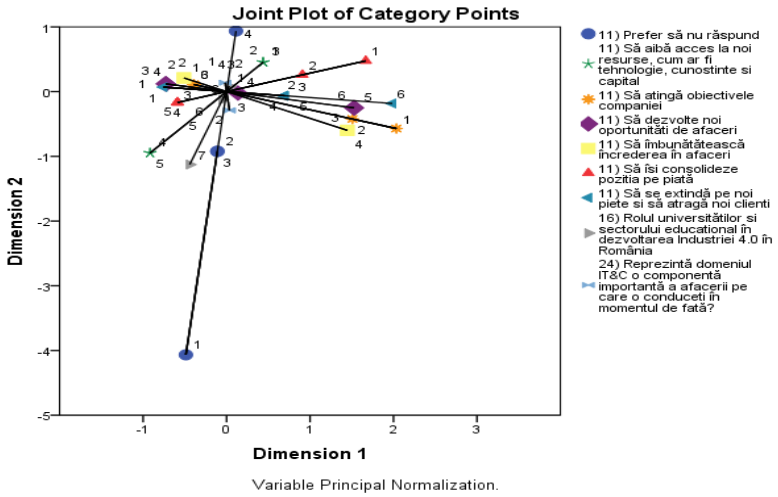

Figure no.4: The intersection of the vectors formed by the variables
Source: *answers processed by the authors in* IBM SPSS 20

As a result of the analysis in fig. no.5, the loading of the component elements on the two dimensions corresponding to each category facilitated the description of the links between them and the degree of association. The distance formed between vectors placed in different quadrants is an eloquent indication of the association between variables. We observe that IT&C field – core component of the business is associated with the role of education in the development of 4.0 technology, as well as with access to new resources and consolidating market position, as strengths when it comes to reasons why entrepreneurs establish business relationships. Again, the point cloud indicates a high degree of association between the variables and their connections.

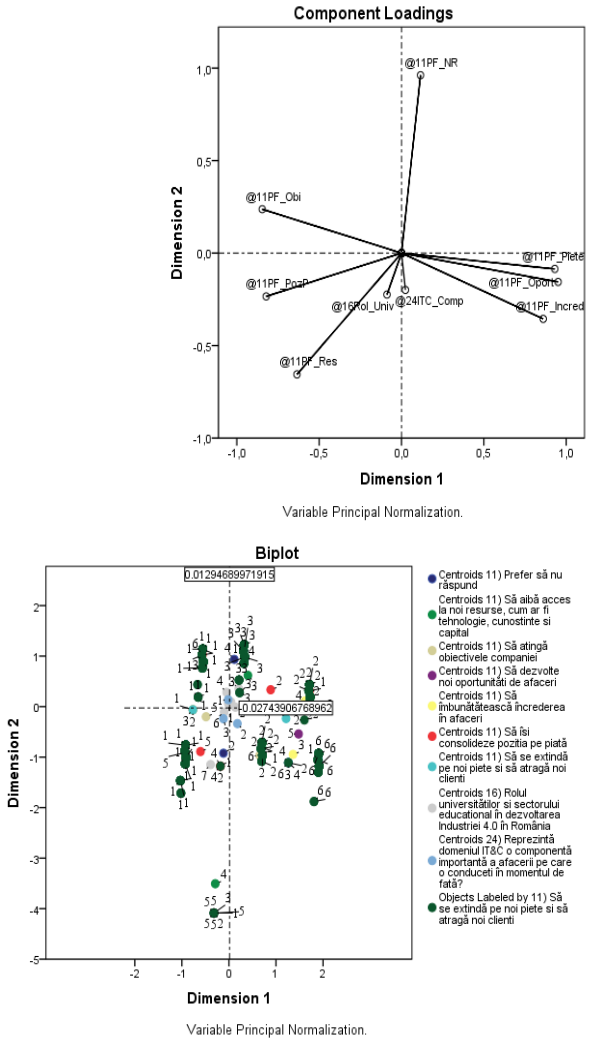

Figure no. 5: Graphical representation of the principal components
***Source*:** *answers processed by the authors in* IBM SPSS 20

The association of a significant number of variables allowed us to validate the third research hypothesis - *The IT&C field is the main direction for the development of Industry 4.0 as well as for the modern, technology-based entrepreneur.*

4. Conclusions and further research

Industry 4.0 represents an opportunity for the economic and technological development of Romania. Unfortunately, at this moment, our country lags behind in the implementation of such technologies compared to other countries in Europe. Investments made in the advanced technology sector are still insufficient.

The Smart Factory is a concept of an intelligent factory that is making its presence felt within Industry 4.0. It uses cutting-edge technologies such as artificial intelligence, the Internet of Things, automation, and robotics to increase the efficiency of production processes.

The main characteristics and defining elements of Industry 4.0 include: interconnectivity, artificial intelligence, the Internet of Things, autonomous vehicles, 3D printing systems, augmented reality, and virtual reality, etc. Our study revealed that, unfortunately, only half of the respondents are aware of the existence of Industry 4.0. To increase awareness and incentivize the adoption of Industry 4.0 technologies, several initiatives should be taken into consideration. Government-sponsored workshops and awareness campaigns focusing on the benefits of adopting advanced technologies could help bridge the knowledge gap. Additionally, introducing subsidies or tax incentives for companies that invest in digital transformation can encourage more businesses to adopt Industry 4.0 practices. Public-private partnerships aimed at demonstrating the practical applications and benefits of these technologies would also be effective in accelerating their adoption. However, it is a positive aspect that entrepreneurs are aware of the importance that technologies can have for the development of their businesses and their strategies.

At the end of our research, we mention some methods to support local entrepreneurship in the context of Industry 4.0, namely: (1) Improving digital infrastructure - the foundation of any business that allows success and global interconnectivity of people. This is not easy to implement operationally, but it is necessary to enable the development of emerging technologies; (2) Standardization and regulations related to IoT devices. These are possible and useful as long as products and services can be interconnected without problems and real-time data exchange can take place; (3) Paying increased attention to education and training in the field of Industry and Technology 4.0. It is understood that to implement and develop such technologies, we need well-prepared people, specialists in the field who are trained in the best implementation practices.

A limitation of the research is that we did not select the participants in the questionnaire based on their competencies, which allowed individuals with still limited knowledge to intuitively express a series of opinions, not always the least subjective, regarding a field they do not know or only think they know.

As a future direction of action, we propose to analyze the studied issue by involving respondents from different professional categories so that the opinions expressed by them can be judiciously analyzed to establish action directions capable of significantly reviving entrepreneurship in Romania, as a basis for intensive development in the new technological era.

Including respondents from diverse professional backgrounds in future research would provide a more comprehensive understanding of the challenges and opportunities faced by different sectors. Such diversity would help to uncover sector-specific issues and needs, leading to more targeted educational programs and policy interventions. For example, perspectives from the agricultural sector might highlight different technological requirements compared to those from the IT sector, allowing for more effective strategies to foster entrepreneurship across Romania.

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